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Quantification of Experimentally Induced-Pleural Effusion in Beagle Dogs: Radiography versus CT and Ultrasonography

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Abstract : This study was performed to quantify the pleural effusion in radiography, ultrasonography and computed tomography(CT) and to evaluate and compare the usefulness of these methods. Normal saline of 10 ml/kg was infused into the pleural space until a final loading volume of 60 ml/kg body weight was reached in six Beagle dogs. The radiographic examination was performed for the detection and quantification of pleural effusion. On the ultrasonographic study, the maximum perpendicular distance was measured between the surface of the lung and the thoracic wall to evaluate pleural effusion. On the CT image, pleural effusion was evaluated as the perpendicular distance to the thoracic surface in the maximum pleural effusion volume on any transverse images with soft tissue window. Statistical analysis was performed using linear regression test. The volume of pleural effusion and measurements of radiography and ultrasonography had no statistical relationship. However, a significant correlation was identified between the volume of pleural effusion and the depth at right ($r^2 = 0.715$), left ($r^2 = 0.745$), and mean right and left depth ($r^2 = 0.844$) on the CT images. All of the thoracic radiographs, ultrasonography, and CT are useful in recognition of pleural effusion. In quantification of pleural effusion, the CT measurement method is superior to radiographic and ultrasonographic measurements.

Key words **:** pleural effusion, CT, ultrasonography, radiography, dog

Introduction

The pleural space normally contains a small amount of fluid that aids in transmission of forces and provides lubrication of the lung surfaces during respiration(10,15,20). Pleural effusion is an abnormal accumulation of fluid within the pleural space and is a common clinical problem in human and small animal(1,11,15,20). Pleural effusion is typically a secondary phenomenon that is induced by underlying condition such as cardiogenic, inflammatory, and neoplastic diseases(15,16).

Clinical signs associated with pleural effusion can vary according to the etiology of the increased fluid volume, the speed of fluid accumulation, and the volume of fluid present(15,20).

Quantification of pleural effusion volume is important because effusion size may impact on the decision of whether to perform thoracocentesis, and possibly influencing the approach used for the procedure. In human, one study demonstrated that ultrasonographic measurement method was preferable to radiographic measurement in quantification of pleural effusions(6). Also, new formula was provided as a method to estimate the accurate volume of pleural effusion with ultrasonography or CT in human(2,12). Previous study approved that about 100 ml of fluid must be present in the pleural space of a medium sized dog for visualization of widened interlobar fissures in radiographs(13). However, no practical and applicable means for accurately quantifying effusion volume in veterinary medicine have been described in previous reports.

The purpose of this study is to quantify the pleural effusion in radiographs, ultrasonographs and CT and to evaluate usefulness of these methods.

Materials and methods

Experimental animals

Six adult Beagle dogs (body weight = 5.8-9.0 kg, mean = 7.5 kg) without clinically abnormal signs related to the cardiovascular and respiratory systems were studied. All dogs were sexually intact (5 female; 1 male). Physical examinations were performed on all dogs. Complete blood count, serum biochemical analysis, thoracic radiography and echocardiography were taken to evaluate the health condition of each dog.

Experimental fluid accumulation and diagnostic imaging

The dogs were premedicated with atropine (0.04 mg/kg,

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SC, Atropine sulfate inj.®, Jeil, Korea) and sedated with thiopental sodium (10-15 mg/kg, IV, Pentothal Sodium, Choongwae, Korea) and maintained with isoflurane during the experiments.

The dogs were positioned right lateral recumbency for insertion of catheter at the left thoracic wall. A small flexible catheter was inserted to the cutaneous tissue at tenth intercostal space and was installed into the pleural space at the seventh or eighth intercostal space. The catheter was filled with saline and was closed in the atmosphere at the time of insertion to avoid air entering the pleural space. After insertion, the catheter was sutured with Roman's sandlion tie. The procedure was confirmed with radiography. During the each scan series, normal saline of 10 ml/kg was infused into the pleural space until a final loading volume of 60 ml/kg body weight was reached. The dog was rolled twice directly after infusion of normal saline and was taken the thoracic radiography, ultrasonography, and CT in order. At the termination of the experiment, we evacuated the saline from the pleural space and recovered more than 50% of the volume infused.

The X-Omat® regular film (Kodak Co., U.S.A) was used with intensifying screen for evaluation of thoracic radiographs. The radiographic examination consisted of ventrodorsal(VD) and left to right lateral projections.

Immediately afterwards, ultrasonography (Sonoace 8800®, Medison, Korea) was performed during expiration with the patient complete dorsal recumbency. The 5 MHz sector transducer was applied at the laterodorsal part of the seventh or eighth intercostal space using plexiglass table in left and right thoracic wall, respectively.

The CT images were obtained with a third-generation whole body scanner (CTmax®, GE, U.S.A). The dogs were positioned dorsal recumbency. Scans were taken at the end of expiration to minimize motion artifacts. Each scan was 5 mm thickness with 10 mm interslice gap. Scan time was 4.8 s/image. The thoracic cavity including entire lung lobes was scanned.

Image evaluation

The radiographs were evaluated for the presence or absence of the pleural effusion. Signs of pleural effusion on thoracic radiographs were defined as: (a) increased homogenous density of the thorax; (b) blunted costophrenic angle; (c) loss of the diaphragm silhouette; and (d) apical capping. For the quantification of pleural effusion in radiographs the sum of thickness of all fissure lines in VD view and the perpendicular distance of pleural effusion at the cranial part of the heart in lateral radiographs were evaluated in each radiographs. The maximum perpendicular distance (thickness) to the upper fissure line was measured and was summed up the measured fissure lines to evaluate the volume of the pleural effusion (Fig 1). The perpendicular distance to the sternum at the location adjoining to the heart was measured in lateral radiographs (Fig 2).

The ultrasonographs were evaluated immediately after radiographic study. The pleural effusion was identified as having an anechoic structure and the maximum perpendicular distance (depth) between the surface of the lung was seen as a hyperechoic reflector and the thoracic wall in right and left intercostal space was measured (Fig 3).

The CT images were evaluated at soft tissue window (WW: +300, WL: −40). On all transverse CT images, the maximum perpendicular distance (depth) between the surface of the lung and the thoracic wall was measured (Fig 4). The depth was measured as the maximum numerical value at right and left hemithorax, respectively.

After all image evaluations were completed, the corresponding CT, ultrasonography and radiographic evaluation were compared.

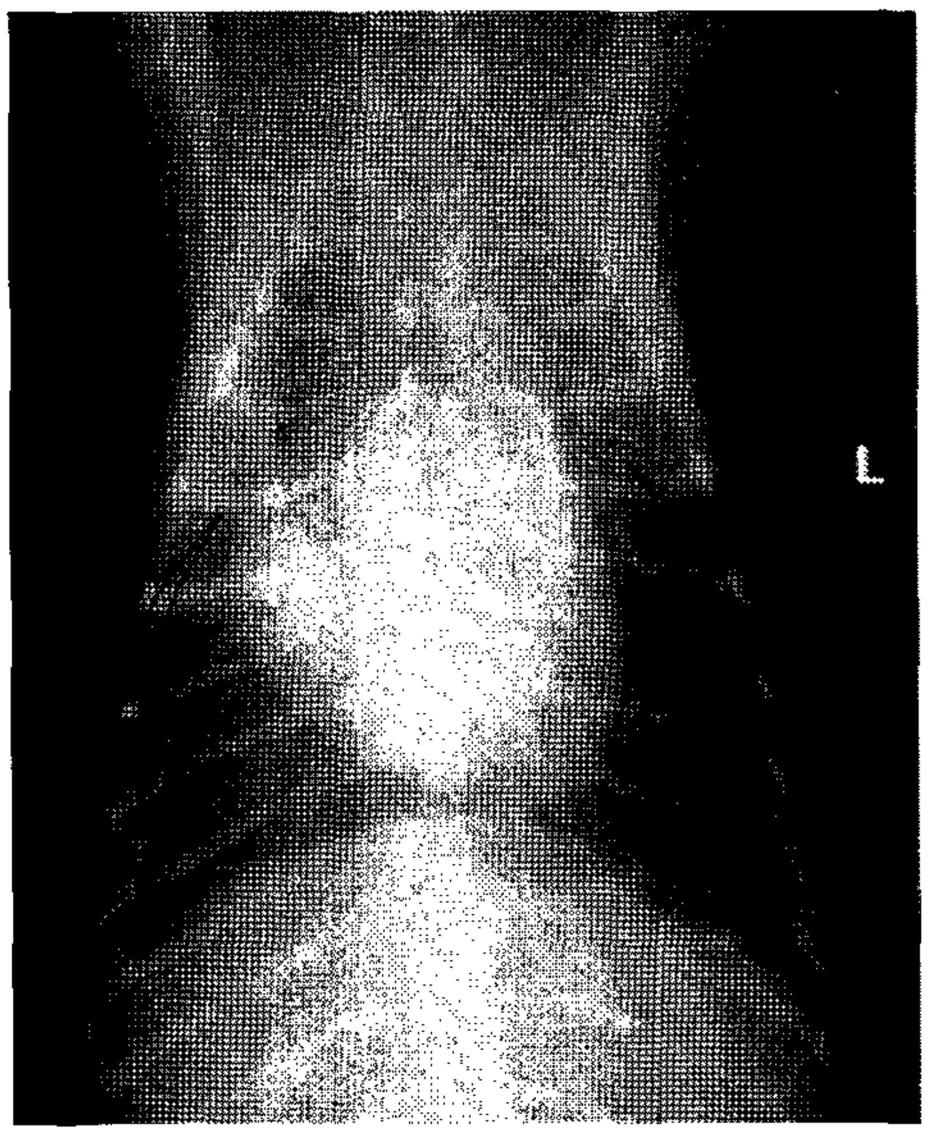

Fig 1. Ventrodorsal radiograph in a dog with experimentally induced pleural effusion. The maximum perpendicular distance to the upper fissure line was measured and was summed up the measured fissure lines.

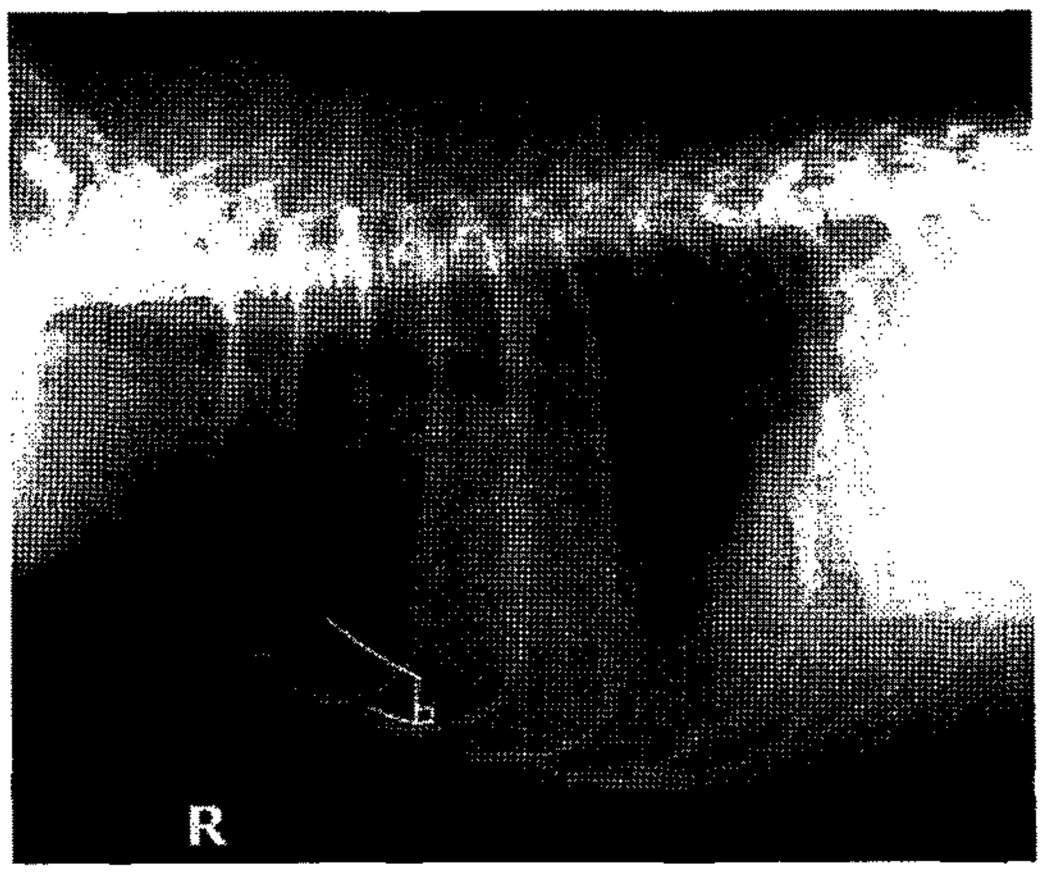

Fig 2. Lateral radiograph in a dog with experimentally induced pleural effusion. Perpendicular distance to the sternum at the location adjoining to the heart was measured (white line).

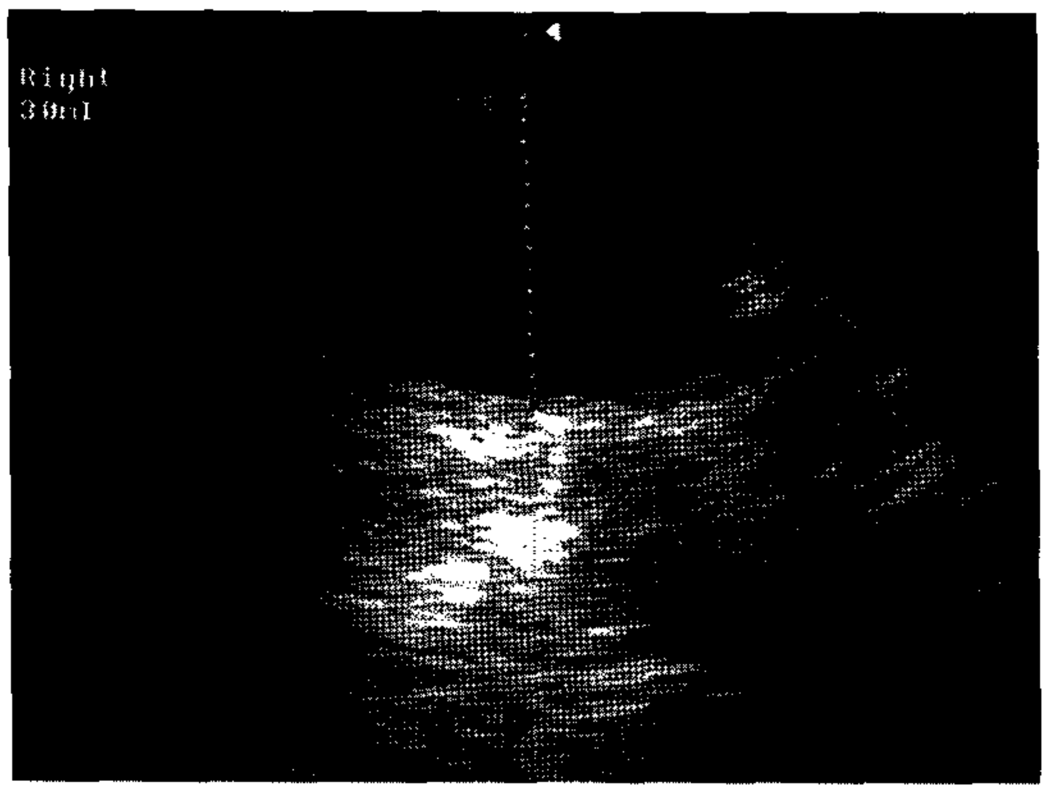

Fig 3. Ultrasonography in a dog with experimentally induced pleural effusion. The pleural effusion was identified as having an anechoic structure and maximum perpendicular distance (dotted line) between the surface of the lung and the thoracic wall was measured.

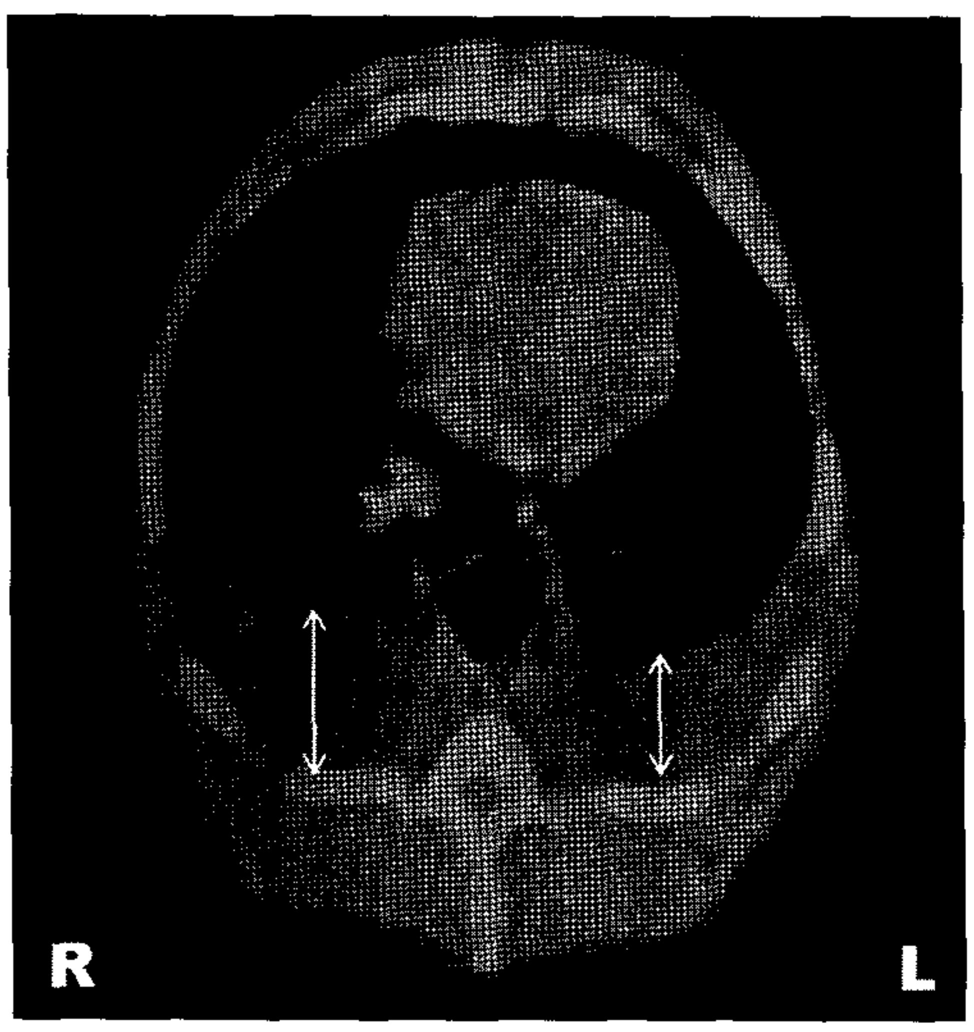

Fig 4. Transverse CT of the thorax in a dog with experimentally induced pleural effusion. The maximum perpendicular distance (depth) between the surface of the lung and the thoracic wall was measured as the maximum numerical value on all transverse images. The depth was measured right (right arrow) and left hemithorax(left arrow), respectively.

Statistical analysis

Correlation between the volume of pleural effusion and the measurements of X-ray, ultrasonography, and CT was examined by linear regression analysis.

Results

On the basis of right lateral and VD view, the pleural effusion was detected in all of the six dogs in each scan series. The radiographic evaluation of pleural effusion was summarized in Table 1.

Increased opacity of the thorax and blunted costophrenic angle were relatively accurate signs in diagnosing small amount of pleural effusion. Detection of all four radiographic signs in table 1 was found when the volume was infused more than 40 ml/kg. The volume of pleural effusion had no correlation with the sum of the thickness of all fissure lines ($r^2 = 0.424$), the perpendicular distance at the location adjoining to the heart ($r^2 = 0.270$) in radiographs (Fig 5).

In ultrasonography, a correlation didn't exist between the volume of pleural effusion and the depth at right ($r^2 = 0.095$), left ($r^2 = 0.134$), and mean of each side ($r^2 = 0.106$), respectively (Fig 6).

On transverse CT images, a significant correlation was identified between the volume of pleural effusion and the depth at right (r2 = 0.715), left (r2 = 0.745), and mean of each side (r2 = 0.844), respectively. Especially, the mean of right and left depth was more correlatable than the measurement of each side in quantifying of the pleural effusion (Fig 7).

Discussion

Recognition of pleural effusions is usually based on thoracic radiographs, ultrasonography, CT and MRI(4-6,8-10,17,21). Radiography is an essential step in evaluating thoracic disease including the pleural effusions(8,17, 21). However, radiographs are notoriously inaccurate in quantifying effusion volumes(6). In human, the presence of pleural effusions is evaluated from supine radiographs using the following signs: increased homogeneous density superimposed over the lung fields, obliteration of the silhouette of the diaphragm, blunted costophrenic angle, apical capping, and accentuation of the minor fissure(7,18,19,22). In this study, ventrodorsal view was performed because the VD view may be useful for evaluation of pleural effusion in dogs(3,13). Radiographic evaluation of pleural effusion was performed in the same manner with human's evaluation except accentuation of the minor fissure. The results of this study showed that increasing amounts of pleural effusion resulted in improving detectability on VD radiographs. However, radiographic signs had comparatively low correlation with the volume of pleural effusion. Using additional radiographic projections such as right lateral view

Table 1. Radiographic evaluation volume of pleural effusion in six dogs

Radiographic findings	No. of dogs by pleural effusion volume (ml/kg)					
	10	20	30	40	50	60
Increased opacity of thorax	3	4	6	6	6	6
Blunted costophrenic angle	1	4	5	5	4	
Loss of the diaphragm silhouette	0	0	3	5	5	5
Apical capping	0	1	0	4	5	5

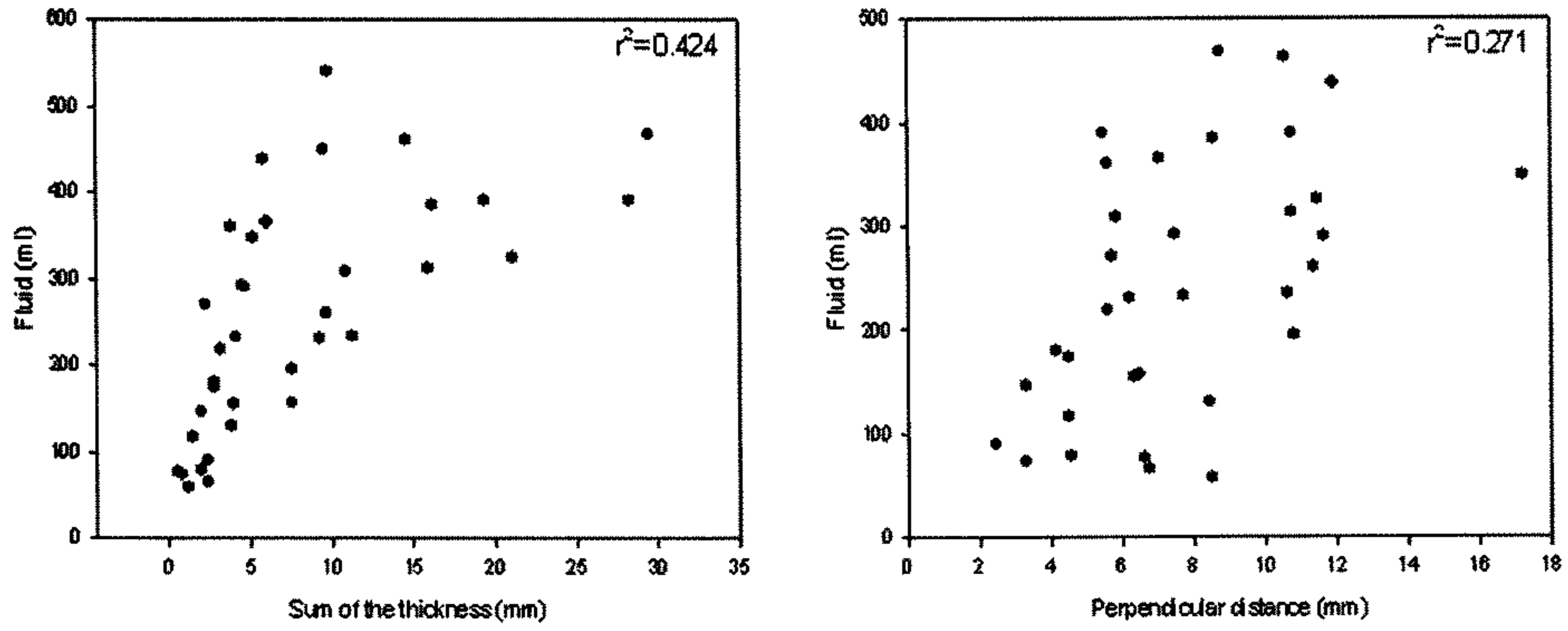

Fig 5. Linear regression analysis of the relationship between the amount of the pleural effusion and the sum of thickness of all fissure lines and the perpendicular distance to the sternum on radiography. A correlation didn't exist between the volume of pleural effusion and the sum of thickness ($r^2 = 0.424$) and the perpendicular distance ($r^2 = 0.270$), respectively.

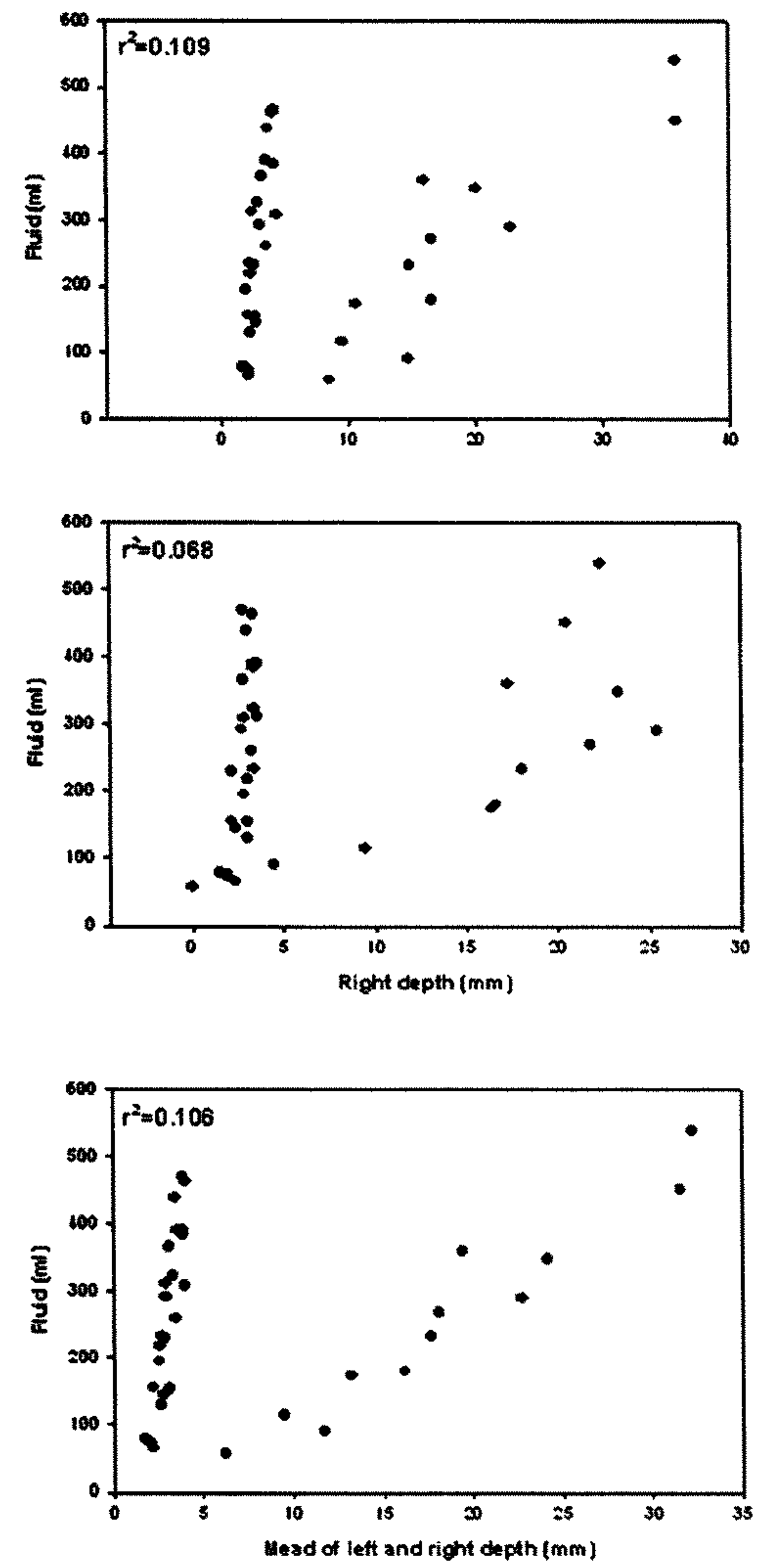

Fig 6. Linear regression analysis of the relationship between the maximum distance and the amount of the pleural effusion on ultrasonography. A correlation didn't exist between the volume of pleural effusion and the depth at left ($r^2 = 0.134$), right ($r^2 = 0.095$), and mean of each side ($r^2 = 0.106$), respectively.

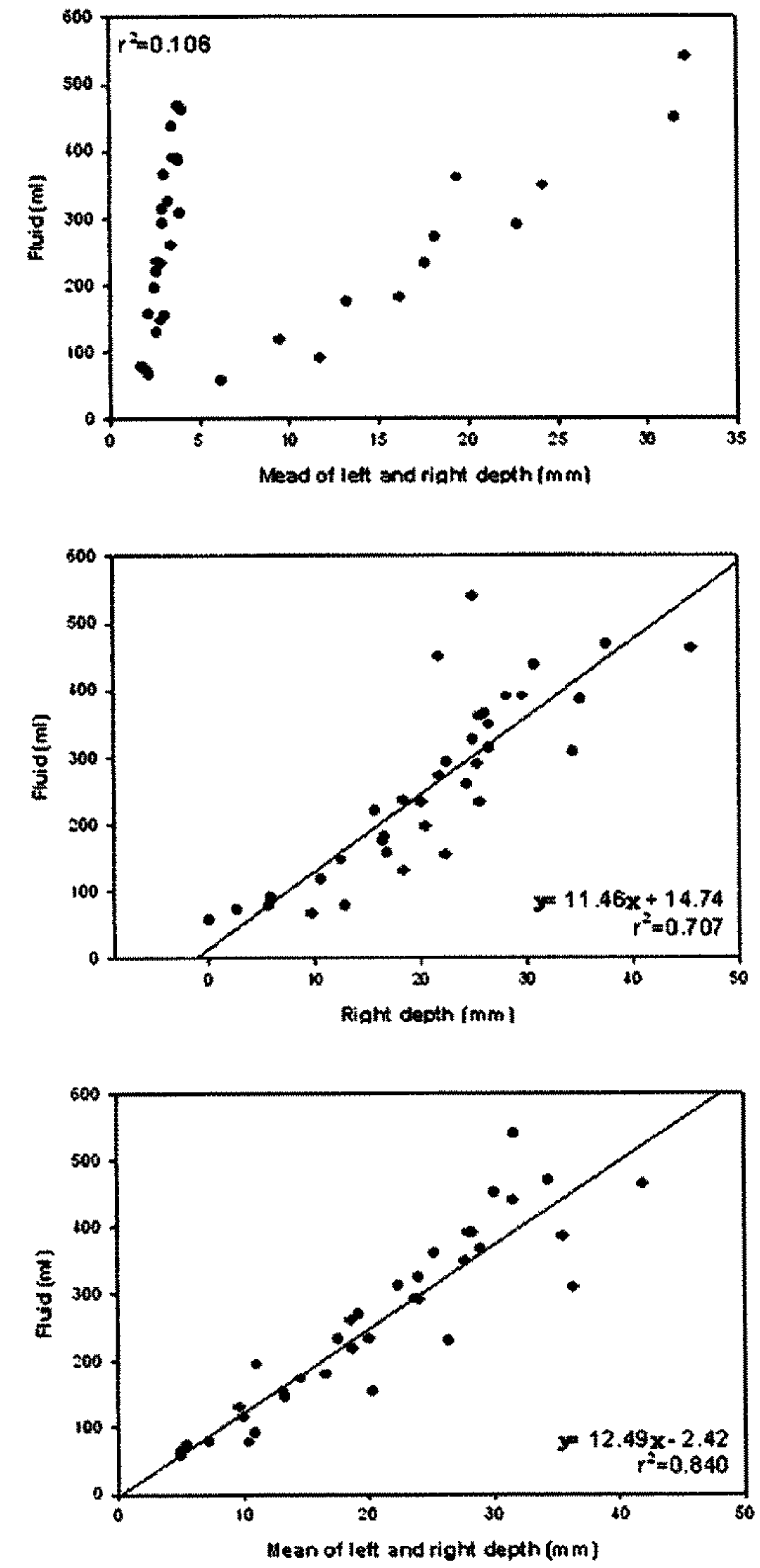

Fig 7. Linear regression analysis of the relationship between the depth and the amount of the pleural effusion on CT. A significant correlation was identified between the volume of pleural effusion and the depth left ($r^2 = 0.745$), right ($r^2 = 0.715$), and mean of right and left depth ($r^2 = 0.844$), respectively. Especially, the mean of each side was detected with high correlation.

would have probably increased the accuracy of detection of pleural effusion(3). The recognition of apical capping was difficult because cranial thorax was piled up with scapula and muscles of forelimb unlike human's musculoskeletal structure. Also, quantification of pleural effusion was attempted on ventrodorsal and right lateral view respectively. The sum of the thickness of the fissure lines in VD radiographs and the perpendicular distance at the location adjoining to the heart had little correlation with the volume of pleural effusion. There were several reasons for lack of correlation in predicting effusion volume in radiographs. Mainly the shape and the distribution of the pleural fluid accumulation influenced the measurement of pleural effusion volume(6). Technical errors including exposure condition of X-ray beam, measurements, and animal's position could be considered. Ultrasonography is useful in the detection of pleural fluid and in guiding interventional procedures such as thoracocentesis and placement of drainage catheters(6,13). Previous study demonstrated that ultrasonographic measurement method was preferable to radiographic measurement in quantification of human's pleural effusions(6). In this study, the volume of pleural effusion in ultrasonography had no correlation with the depth by linear regression analysis at right, left, and mean of each side, respectively. The discrepancy might be caused by the different thoracic shape, scan angle, location of fluid pools depending on position such as rotation and inclination, and difficulty in detection of lung margin.

Thoracic CT scanning has been utilized in veterinary medicine gradually because it can provide additional information that contribute management, therapy and potential follow-up of patients. Also, CT can be used for further characterization of pleural fluid type such as pleural exudates and transudates(3) and may be used to guide interventional procedures(1, 21). A formula was provided as a method to estimate accurately and easily the volume of pleural effusion with CT in human(12). In the present study, quantification of pleural effusion volume using thoracic CT was statistically significant correlation with the depth at right, left, and mean of each side, respectively. The mean of right and left depth was especially detected with high correlation. The reason for this result was considered that estimation of patient's position and confirmation of pleural effusion margin in CT was comparatively easy to ultrasonography or thoracic radiography. Also, it was easy to measure the quantification of pleural effusion volume by CT.

The formula for quantification of pleural effusions from thoracic CT was introduced as d^2*l (d: the greatest depth, l: the cephalad to caudal length of an effusion) in human(12). The fomula was inapplicable to the quantification of pleural effusion in dogs with different thoracic cavity structure leading to the lower ratio of the thoracic depth to the thoracic width than human's. A limitation of this study is the lack of a comparative study among the breeds possessed different anatomy of thoracic cavity. Another limitation is that correlation between the pleural effusion volume and measurement in imaging is hard to foresee when the pleural effusion volume is more over than 60 ml/kg.

In summary, thoracic radiographs should still be considered the first line of imaging the thorax, however, can be indeterminate in quantification of the pleural effusion volume because of the difference in the shape of the pleural fluid accumulation. Ultrasonography was easily performed in dorsal recumbency and detected small amount of pleural effusion. However, it was not a suitable method for quantification of pleural effusion in this study. It was thought that CT is more useful and reliable method than radiography and ultrasonography for quantification of pleural effusion volume.

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References

1. Arenas-Jimenez J, Alonso-Charterina S, Sanchez-Paya J et al. Evaluation of CT findings for diagnosis of pleural effusions. Eur Radiol 2000; 10: 681-690.
2. Balik M, Plasil P, Waldauf P et al. Ultrasound estimation of volume of pleural fluid in mechanically ventilated patients. Intensive Care Med 2006; 32: 318-321.
3. Brinkman EL, Biller D, Armbrust L. The clinical usefulness of the ventrodorsal versus dorsoventral thoracic radiograph in dogs. J Am Anim Hosp Assoc 2006; 42: 440-449.
4. Davis SD, Henschke CI, Yankelevitz DF, Cahill PT, Yi Y. MR imaging of pleural effusions. J Comput Assist Tomogr 1990; 14: 192-198.
5. Dechman G, Mishima M, Bates JH. Assessment of acute pleural effusion in dogs by computed tomography. J Appl Physiol 1994; 76 :1993-1998.
6. Eibenberger KL, Dock WI, Ammann ME et al. Quantification of pleural effusions: sonography versus radiography. Radiology 1994; 191: 681-684.
7. Emamian SA, Kaasbol MA, Olsen JF, Pedersen JF. Accuracy of the diagnosis of pleural effusion on supine chest X-ray. Eur Radiol 1997; 7: 57-60.
8. Evans AL, Gleeson FV. Radiology in pleural disease: state of the art. Respirology 2004; 9: 300-312.
9. Frola C, Cantoni S, Turtulici I et al. Transudative vs exudative pleural effusions: differentiation using Gd-DTPA-enhanced MRI. Eur Radiol 1997; 7: 860-864.
10. Kocijancic I, Vidmar K, Ivanovi-Herceg Z. Chest sonography versus lateral decubitus radiography in the diagnosis of small pleural effusions. J Clin Ultrasound 2003; 31: 69-74.
11. Light RW. Pleural effusion. In: Bouros D. Pleural disease, 3rd ed. Williams and Willkins, Baltimore, 1995: 36-74.
12. Mergo PJ, Helmberger T, Didovic J et al. New formula for quantification of pleural effusions from computed tomography. J Thorac Imaging 1999; 14: 122-125.
13. Myer CW. Radiography review: the vascular and bronchial patterns of pulmonary disease. Vet Radiol Ultrasound 1980; 21: 156-160.

14. Nandalur KR, Hardie AH, Bollampally SR, Parmar JP, Hagspiel KD. Accuracy of computed tomography attenuation values in the characterization of pleural fluid: an ROC study. Acad Radiol 2005; 12: 987-991.
15. Nelson OL. Pleural effusion. In: Ettinger SJ, Feldman EC, editors. Textbook of veterinary internal medicine, 6th ed. Elsevier sounders, Philadelphia, 2005: 204-207.
16. Porcel JM, Light RW. Diagnostic approach to pleural effusion in adults. Am Fam Physician 2006; 73: 1211-1220.
17. Prather AB, Berry CR, Thrall DE. Use of radiography in combination with computed tomography for the assessment of noncardiac thoracic disease in the dog and cat. Vet Radiol Ultrasound 2005; 46: 114-121.
18. Raasch BN, Carsky EW, Lane EJ, O'Callaghan JP, Heitzman ER. Pleural effusion: explanation of some typical appearances. Am J Roentgenol 1982; 139: 899-904.
19. Ruskin JA, Gurney JW, Thorsen MK, Goodman LR. Detection of pleural effusions on supine chest radiographs. Am J Roentgenol 1987; 148: 681-683.
20. Saunders NA, Sleeper M. Pleural transudates and modified transudates. In: King LG. Textbook of respiratory disease in dogs and cats, 1st ed. Saunders, Philadelphia, 2004: 587-597.
21. Warakaulle DR, Traill ZC. Imaging of pleural disease. Imaging 2004; 16: 10-21.
22. Woodring JH. Recognition of pleural effusion on supine radiographs: how much fluid is required? Am J Roentgenol 1984; 142: 59-64.

비글견에서 실험적으로 유발한 흉수의 정량 평가: 방사선, 컴퓨터단층촬영 및 초음파 검사 비교

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요 약 : 흉수량은 흉수천자의 실시 여부 및 진단과 치료에 이용되는 방법의 결정에 영향을 미치므로 흉수량 측정은 중요하다. 본 실험의 목적은 흉수를 정량화하기 위해 흉부 방사선 및 초음파와 컴퓨터단층촬영을 시행하여 그 결과를 비교하고 정확도를 측정하는데 있다. 임상적으로 건강한 6 마리의 비글견을 이용하여 생리식염수를 최종 용량이 60 ml/kg 될 때까지 체중당 10ml씩 흉강에 주입하면서 흉부 방사선 검사, 초음파 검사, CT 검사를 차례로 실시하였다. 흉부 방사선 사진에서 흉수의 유무 평가 및 흉수 정량화를 실시하였으며 초음파 영상에서 흉수량은 폐의 표면과 흉강벽 사이의 최대 수직 거리를 측정하여 평가하였다. CT 영상에서 흉수량은 soft tissue window에서 평가하였으며 최대 흉수량을 나타내는 영상에서 최소 수직거리를 측정하였다. 흉수량과 흉부 방사선 사진 및 초음파 영상에서의 측정치와 통계학적으로 유의적인 결과를 얻지 못했다. 그러나 CT 검사에서의 측정값과 흉수량과의 유의적인 관계를 나타내었다. 특히 흉수의 정량화에서 좌우측 측정치의 평균값이 좌우측 각각의 값보다 더 높은 정확도를 나타내었다. 흉수를 확인하기 위해서는 흉부 방사선 검사 초음파 검사 및 CT 검사가 모두 가능하나 흉수를 정량화하기 위해서는 흉부 방사선 및 초음파 검사보다 CT 검사가 유용함을 확인하였다.

주요어 : 흉수, 컴퓨터단층촬영, 초음파 검사, 방사선 검사, 개